The Impact of Space Weather on Inmarsat Satellite Fleet Operations

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Topics

Overview of the Inmarsat satellite fleet

Operational impacts from space weather events

- **Short term (e.g. single event upsets)**
- **Longer term (e.g. solar array performance)**

Use of space weather observations

Future satellite design considerations and conclusions

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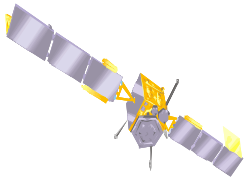
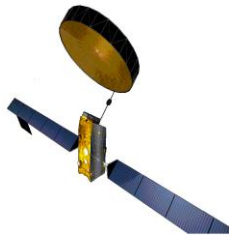
Inmarsat's Fleet

- 10 geostationary mobile communication satellites (L-band user link)
- 4 x Inmarsat-2 (2 still operational)
  - Launched 1990 to 1992
  - British Aerospace Eurostar 1000 platform
  - Providing voice, fax and maritime safety of life services



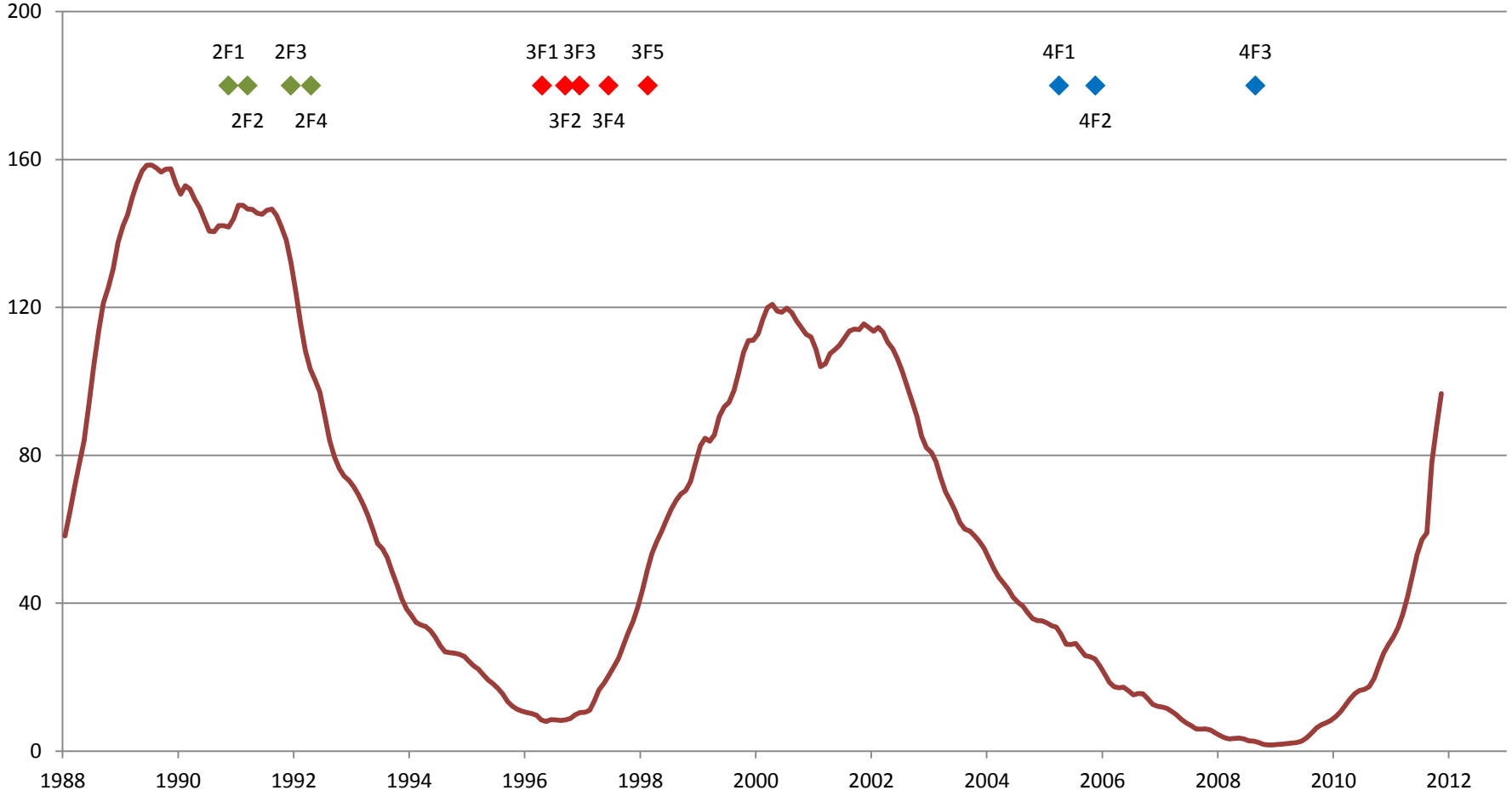
- 5 x Inmarsat-3
  - Launched 1996 to 1998
  - Lockheed Martin A4000 platform
  - Spot beam services and navigation

- 3 x Inmarsat-4
  - Launched 2005 to 2008
  - Astrium Eurostar 3000 platform
  - Spot beam services and navigation



- 4 more satellites on-order
  - Astrium/TAS Alphasat (2013)
  - 3 x Inmarsat-5, Boeing 702s (2013/14)

Satellite Launch Date vs Avg Sunspot Number



Operational Consideration - 1

- In the 170+ yrs of satellite operations we haven't changed a planned operational activity due to predicted or reported space weather activity….why?
  - Naivety, lack of timely/accurate actionable information or good design/operations? Or most likely a combination of these!
- …..that is not to say we don't see the effects of space weather
  - We see sporadic single event upsets (SEUs) across the fleet. Handled either using on-board redundancy or via ground system detection and recovery
  - Some of our satellites can suffer a SEU which results in a comms payload trip-off. Our ground control system has automation functionality to allow the detection and automatic quick recovery (within ~60 sec) rather than many minutes required for manual recovery.
  - We do see attitude disturbances coincident with periods of high solar activity. We respond reactively rather than pre-empting any possible impact e.g. we have aborted a number of manoeuvres
  - Long term exposure is monitored e.g. UV solar array degradation. Luckily to date degradation is less than predicted.

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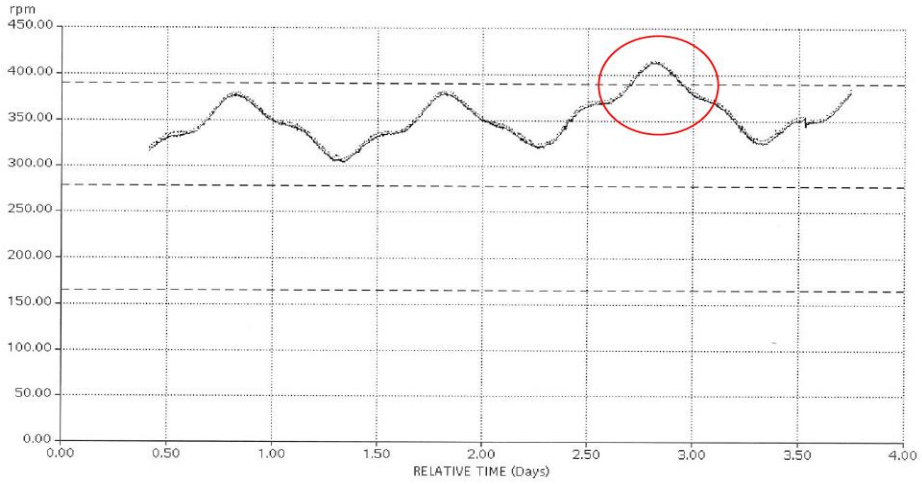
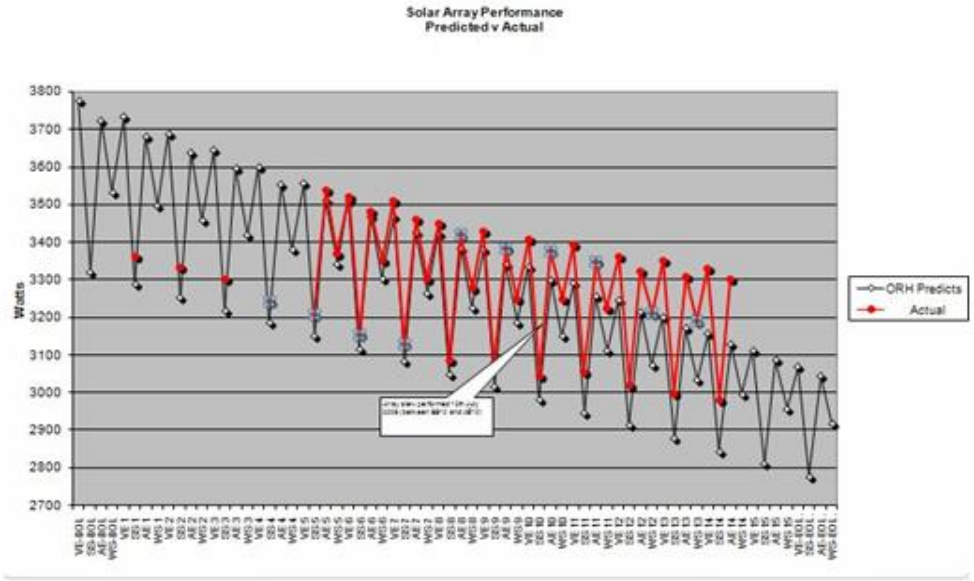
Operational Consideration - 2





Use Of Space Weather Data

- Our operations teams do subscribe to the NOAA notifications, information and web services
  - Used to provide context within which satellite issues are analysed
  - Post event analysis
- The lack of real-time actionable data means that we don't change our operational plan.
- What would help?
  - More accurate estimates of arrival time/location/magnitude of particles flux, magnetic orientation etc
  - Predicted effect at various GEO longitudes
- We also have to be careful of the 'management effect'; a lot of people not related to operations also subscribe to these notifications and can generate significant 'noise'. Also peaks of interest from the media…

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Conclusions

- The Inmarsat satellites are certainly susceptible to space weather conditions, but they have been specifically designed to minimise the operational and service impacts caused by of these types of events.
- With our 170+ yrs of on-orbit operational heritage, which has included 9 satellites through a full solar cycle, Inmarsat has not to date suffered any service outage or permanent satellite component failure directly attributable to a solar or a more general space weather event.
  - This is a good indication that the engineering and oversight of the design of our satellites, some of which dates back over 25 years, has provided the level of protection expected
- Inmarsat doesn't currently use space weather information as a driver to direct operational decisions, but rather for post event analysis
- …..however, changes in satellite technology may require us to do so in future.

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